

fog." This term should be applied to cloud banks of considerable continuity and density,⁴ and not confused with cirrus (high altitude) clouds or with ordinary "low fog."

Possibly we may establish a safer criterion by determining whether a shadow is being cast. We have observed that in some cases the record varies over 5 microamperes, but the total intensity is not much reduced below the maximum for a clear day. In these cases it was noticed that shadows were cast. On the other hand, when the cloud density increases sufficiently a shadow is no longer cast and the record sinks to 6 microamperes or less. As an illustration of some of these points we may cite the record for the day of the total solar eclipse, April 28, 1930.

⁴ See Carpenter, Ford A.: *The Climate and Weather of San Diego*. 1913, pp. 5-7.

(See fig. 7.) Here it will be noticed that the trace becomes quite continuous below 12 microamperes (40 on the chart) having the smoothness of a record for a clear day but forming a beautiful V-shaped indentation in the record.

Kimball,⁵ in several articles dealing with the design, construction, and performance of the pyranometer, refers to irregularities in the traces of the instrument on apparently clear days but comes to no definite decision regarding the probable cause of the irregularities. On another occasion he states that they may be caused by smoke. At a location like La Jolla, this hypothesis is ruled out, since the atmosphere is always smoke-free except on rare occasions when there are forest fires.

⁵ Kimball, Herbert H.: *Records of Total Solar Radiation Intensity and Their Relation to Daylight Intensity*. MONTHLY WEATHER REVIEW, October, 1924, vol. 52, p. 473, fig. 5.

SOME CHARACTERISTICS OF CONTINUOUS RECORDS OF THE TOTAL SOLAR RADIATION (DIRECT+DIFFUSE) RECEIVED ON A HORIZONTAL SURFACE

By HERBERT H. KIMBALL

In the paper preceding this, Gorton and Chambers have pointed out some interesting relations between the character of solar radiation records and the condition of the sky. Ångström¹ has already noted some of these relations at Stockholm, and especially the increased intensity with the sun shining between broken clouds.

In an earlier paper entitled "On Continuous Radiation Records and Their Bearing upon Geophysical Problems." (Särtryck ur Förhandlingar 17: deskandinaviska naturforskarsamfundet i Götting, 1923) he discusses the cloud formation during the passage of a cold-wave front at Stockholm on August 4, 1922. The formation of a uniform cloud layer preceded the arrival of the cold air at the surface by an appreciable time interval, and breaks occur in this cloud layer at uniform intervals of two hours. This is explained as follows:

The upper boundary of the cold wave is in general subjected to a pronounced wave formation. Sometimes waves of higher orders are well developed. As a rule the uniform cloud layer appears at the wave tops, the breaches in the cloud layer at the valleys, but exceptions therefrom sometimes occur. In the special case referred to above the breaches in the cloud layer have occurred almost exactly at the lowest points of the waves.

Apparently, atmospheric waves sometimes occur without forming visible clouds. For example, in the MONTHLY WEATHER REVIEW for September, 1915, volume

43, page 441, in Figure 1 are plotted logarithms of solar radiation intensity against air mass, measured on unusually clear days. With a sky of uniform clearness throughout, the plotted values should fall on a line only slightly concave upwards. Actually, however, the values fall on a wavy line, and especially those for Washington, during the afternoon of February 28, 1915, and for Mount Weather, Va., during the morning of September 28, 1914.

Attention has also been called to the effect of smoke on the solar radiation intensity. See, for example, MONTHLY WEATHER REVIEW, volume 52, page 478, Figure 5, October, 1924, and volume 53, page 147, Figure 1, April, 1925. The first of these reproduces records of intensity of the total solar radiation received on a horizontal surface at the university station, Chicago, Ill., and its depletion by smoke on both a cloudless and a cloudy day. The second shows the depletion of direct solar radiation intensity at normal incidence at the American University, District of Columbia, by a smoke cloud that was brought over the university from the city by an east wind. Clouds of less density frequently cause depressions in the records obtained in the vicinity of any city.

It is apparent that much valuable information about sky conditions may be obtained from continuous records of the intensity of solar radiation as received on either a horizontal surface or on a surface normal to the incident rays.

¹ Ångström, Anders. Recording solar radiation. Medd. Från Statens Meteorologisk-Hydrografiska Anstalt, Band 4, No. 3, 1928.

COMPARISON OF ROOF AND GROUND EXPOSURE OF THERMOMETERS

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It is generally conceded that the average temperature readings obtained from properly exposed thermometers in the Plains States, where the ground surface is level or slightly rolling, agree quite closely within a radius of from 15 to 25 miles. What, however, is the relation between official temperatures taken in downtown sections of middle-western cities and their suburbs? In other words, do official temperatures taken on high buildings of cities reflect conditions under which people live in the residence sections? It must be remembered that in a great percentage of the larger cities the usual practice is to locate the thermometers on roofs of high buildings,

while in the suburbs, the thermometers are more likely to be exposed over a ground surface. In order to investigate this question a 6-year record of daily maximum and minimum temperature readings was obtained in Topeka, Kans.

The thermometers used in this study were of standard pattern, compared for accuracy, and exposed in standard shelters having louvered sides and double-decked roofs. These favor the free circulation of the passing air, but do not absorb any added heat due to radiation or reflection from near-by objects or from the direct rays of the sun. One set, that of the Weather Bureau office, was

located 10 feet above the flat roof of a 6-story building, making an actual elevation of thermometers 92 feet above street level, in the center of the business district, and the other 5½ feet above the ground at a point a mile and a half away in the residential section. The size of the ground shelter is 21 by 32 inches; it has not a broad platform underneath it. The ground surface at both places is approximately the same elevation above sea level.

During the period of comparative readings some of the lowest readings ever recorded in the vicinity, as well as the highest on record in 44 years, occurred. This should eliminate the objection that just average conditions had prevailed during the experiment and extreme conditions might have altered the results obtained.

In most instances the individual monthly averages obtained from the ground surface readings were higher. Occasionally, though, during no definite seasons, the opposite was true. The wind movement and presence of snow and ice on the ground seem to have been the most apparent factors in making the differences so far as the study indicates. Taking the monthly averages for the six years into discussion, it is found that these averages compensate the individual monthly inconsistencies and the ground exposed readings exceed the roof readings each month, and for the entire period average by 0.6°. This fact in itself eliminates any need for correction for altitude, as the ground instruments are less than 100 feet below those on the roof. In case there was a noticeable altitude effect, it would tend to lessen the differences instead of increasing them.

The monthly mean maximum and minimum temperatures and extremes add more to the study than do the average readings. The ground-exposed maximum thermometer averaged 1.9° higher than the roof thermometer, while the minimum readings averaged 0.6° less. This may be accounted for by stating that the radiation effect at the ground should be greater than on the roof, where air passage is less hampered. This conclusion is indicated by the tables giving the monthly extremes and the extremes for the entire period. Whereas the monthly averages do much towards eliminating the observed discrepancies, the daily extremes exhibit examples of the various individual factors that tend to separate or draw together the readings.

For an example of wind effect, let us refer to several dates selected at random. On April 24, 1926, the wind, as recorded at the Topeka Weather Bureau office, averaged 19.9 miles per hour for the day, which is above the daily average wind movement. The high wind kept the air mass in continual turmoil, the result being a minimum temperature at the ground of 45° and on the roof 46°.

On June 9, 1927, the daily wind averaged 16.7 miles per hour and the minimum readings at both places were the same, 66°. On September 11, 1928, the wind averaged 13.0 miles per hour and the minimum on the ground was 64° while on the roof it was 63°. On December 2,

1929, the wind averaged 10.3 miles per hour, and again both thermometers registered the same, 10°.

Radiation effect is greater if the wind movement is light, permitting the air mass to become stagnant. The dates selected to illustrate this part of the wind factor are as follows: On April 26, 1926, with an average wind movement of 5.6 miles per hour, the minimum on the ground read 37° and the roof thermometer 42°. On July 2, 1927, the wind averaged 5.5 miles per hour and the ground minimum was 57° while the roof minimum was 64°. On September 15, 1928, with an average wind movement of 3.3 miles per hour, the ground thermometer registered 54° and the roof thermometer 61°. On November 1, 1928, the wind averaged 4.9 miles per hour and the minimum on the ground was 29° while on the roof it was 34°. All the days considered in these cases were either clear or mostly so. It will be observed that the days selected represent each quarter of the year which indicates that this factor is not limited to any particular season.

For cases to demonstrate what effect a snow blanket has on the ground temperature we refer to the period of January 12 to 16, 1927. Snow several inches in depth occurred on the 12th and 13th, leaving 4 inches on the ground at the close of the 13th. The next morning with a clear sky and wind averaging 10.2 miles per hour, the ground thermometer registered 5° while the roof thermometer registered 8°. Practically the same sky and wind conditions prevailed through the 16th. On the 15th the ground thermometer read 14° below zero and the roof thermometer 9° below zero. On the 16th the ground minimum was 16° and roof reading 23°. The period of January 22 to 25, 1930, also illustrates this point. Previous to the 22d, snow had fallen and the ground was covered to a depth of 9.0 inches. The sky was clear from the night of the 21st to the morning of the 25th. The average wind movement the 21st to 22d was about 5 miles an hour. The ground thermometer that morning read 19° below zero and the one on the roof read 13° below zero., which by the way, is the lowest recorded at the Weather Bureau in 11 years. The wind movement from the 23d to the 25th averaged between 9 and 10 miles per hour. On the morning of the 23d, the ground reading was 7° below zero while the roof reading was 1° above zero. On the 24th the low point at the ground was 9° compared to 12° on the roof. The morning of the 25th the ground thermometer indicated 3° and the one on the roof 11°.

The daily maximum readings did not show as great differences as the minimums, but this can be accounted for by the fact that the maximum generally occurs in the latter part of the afternoon when the wind movement is at its highest, resulting in the air mass at the ground at that time being about as active as on the roof. For this reason the maximum readings on the roof and ground agreed uniformly within one or two degrees, and any number of times were exactly the same. A case in this connection was August 3, 1930, when the Weather

Bureau thermometer registered 110°, which was the highest reading ever recorded in 44 years. The ground thermometer corresponded exactly. The sky was mostly clear and the wind averaged 11.9 miles per hour.

The slightly higher day readings and lower night readings signified that the daily range must be proportionately greater at the ground. This varied from time to time. For the entire period the monthly mean daily ranges differed by 2.4°. The daily range varied from day to day, sometimes being close together and then again at wide variance. The greatest differences occurred during quiet spells when the radiation effect was greatest.

Actual practice in the United States Weather Bureau is to employ ground exposure at some 4,500 cooperative stations and at as many first-order stations as possible. Roof exposures are accepted only through necessity, never from choice.

The results of the comparative readings are summarized on a monthly basis in the table below.

TABLE 1.—Summary of comparative readings, monthly means, and extremes

Stations	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Monthly means, ground.....	26.9	37.6	46.3	57.1	64.9	73.0	79.6	77.6	70.5	57.8	43.2	31.8	55.5
Monthly means, roof.....	26.6	37.0	45.0	56.0	64.4	72.2	79.0	77.3	69.8	57.9	42.6	30.8	54.9
Monthly means, maximum ground.....	36.9	48.7	58.9	68.8	76.5	83.9	91.2	89.2	81.8	69.4	54.0	42.0	66.8
Monthly means, maximum roof.....	35.6	46.7	56.1	66.1	74.8	82.0	89.3	88.0	80.0	68.4	52.3	39.9	64.9
Monthly means, minimum ground.....	16.9	26.5	33.7	45.5	53.3	62.1	68.0	65.7	59.2	46.1	32.3	21.6	44.2
Monthly means, minimum roof.....	17.6	27.4	34.0	45.9	53.9	62.4	68.7	66.6	59.6	47.4	32.9	21.7	44.8
Absolute maximum, ground.....	66	83	89	93	95	99	105	110	102	93	83	68	110
Absolute maximum, roof.....	68	83	88	93	96	100	104	110	101	93	84	68	110
Absolute minimum, ground.....	-19	-11	0	14	34	46	51	49	35	16	5	-9	-19
Absolute minimum, roof.....	-13	-7	4	17	35	49	52	52	38	16	10	-9	-13

FURTHER NOTES ON THE EFFECT OF WEATHER ON APPLE YIELDS

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The effect of temperatures on apple yields was studied during 1927 by the author and the results published in the Monthly Weather Review.¹ The effect of precipitation, however, was not considered at that time as the purpose of the study was to substantiate the theory that spring temperatures were largely a determining factor in apple production. The precipitation by months was studied rather casually in a preliminary survey, but no definite relationship was established. However, a bulletin of the New York Agricultural Experiment Station by R. C. Collison and J. D. Harlan² was forwarded by the senior author for information as regards its conclusions. This publication contains the results of a rather exhaustive survey of an orchard of 50 Rome Beauty apple trees in New York. The conclusions drawn are that temperature departures from normal are not an important factor influencing yield, but that precipitation departures from normal are very important, especially those for the period from July 16 to September 1. It is also shown that the most critical period of these six weeks is that between July 31 and August 15. These conclusions, if they could be correctly applied to the entire State, would depreciate the spring temperature theory. In order to check these conclusions with State yields it was decided to collect rainfall data from the temperature stations and find such relationships as might exist.

The daily precipitation for three months, June to August, inclusive, was obtained and weekly amounts computed. Thus, the weekly periods covered the time from June 1 to August 30 and should show the critical period by the magnitude of the correlation coefficients.

The individual correlation coefficients for these 13 weeks are given below:

Week ending—	Correlation coefficient	Week ending—	Correlation coefficient
June 7.....	-0.14	July 26.....	0.07
June 14.....	.23	Aug. 2.....	-.06
June 21.....	.21	Aug. 9.....	-.05
June 28.....	-.18	Aug. 16.....	-.22
July 5.....	.36	Aug. 23.....	.20
July 12.....	-.29	Aug. 30.....	.14
July 19.....	.06		

The magnitude of the coefficients is very small, the largest being only 0.36, which is hardly large enough to consider. There is some significance, however, in the largest coefficients occurring in pairs, as it would appear from this 2-week periods are of more importance than single weeks. The coefficients of these 2-week periods with yield, by multiple correlation methods, were: June 7-21, 0.26; June 29-July 12, 0.59; August 9-23, 0.29. The increase of the coefficient for the weeks June 29-July 12, from 0.36 to 0.59, is rather striking. This is due to the fact that, while the two weeks have a positive and negative relationship with yields, the correlation between them is positive; thus the relation of both with yield is very much better in combination than separate.

The three 2-week periods were combined in a multiple correlation, giving a coefficient of 0.64, or only 5 points better than the coefficient of the weeks June 29-July 12. These six variables then were put into an equation in order to compute yields from them. The equation follows:

$$\bar{X} = 1.14 A - 0.31 B + 3.16 C - 5.30 D + 0.95 E + 2.34 F + 8.22$$

The letters A, B, C, etc., refer to the single weeks, June 14, June 21, July 5, etc.

The computed yields from this equation gave a reduction of the standard deviation of 23 per cent. The reduc-

¹ Mattice, W. A. (1927): The Relation of Spring Temperatures to Apple Yields. MONTHLY WEATHER REVIEW, 55, 10: 456-459.

² Collison, R. C., and Harlan, J. D. (1927): Annual Variation in Apple Yields—A Possible Cause. Technical Bulletin No. 126, New York Agricultural Experiment Station, Geneva, April, 1927.